# Technical Note

1966-24

S. B. Russell

# Haystack Display Translator

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

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*S. B. RUSSELL*

*Group 62*

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ABSTRACT

The Haystack Display Translator provides decimal displays of the Haystack antenna azimuth and elevation position angles, command azimuth and elevation angles, azimuth and elevation bias angles, or alternately, azimuth and elevation center of scan angles, and EST and GMT displays. Each of the 19-bit binary angle inputs is multiplied by a scale factor, converted from binary to BCD, and stored for display. EST in BCD is stored for display and also converted to GMT and stored for display.

Accepted for the Air Force
Franklin C. Hudson
Chief, Lincoln Laboratory Office

# HAYSTACK DISPLAY TRANSLATOR

## GENERAL

The Haystack Display Translator is a system which provides decimal displays of the Haystack antenna azimuth and elevation position angles, command azimuth and elevation angles, and azimuth and elevation bias angles or alternately azimuth and elevation center of scan angles. Local*time and Greenwich mean time displays are also provided. Table 1 shows the set of binary input words which are accepted by the Display Translator and Table 2 shows the set of output words.

TABLE 1

Display Translator Input Words

| WORD | LENGTH | LEAST SIGNIFICANT BIT VALUE |
|---|---|---|
| ANTENNA AZIMUTH | 19 bit | $\frac{360}{2^{19}}$ |
| ANTENNA ELEVATION | 19 bit | $\frac{360}{2^{19}}$ |
| COMMAND AZIMUTH | 19 bit | $\frac{360}{2^{19}}$ |
| COMMAND ELEVATION | 19 bit | $\frac{360}{2^{19}}$ |
| AZIMUTH BIAS (COMPUTER MODE ONLY) | 19 bit AND SIGN | $\frac{360}{2^{19}}$ |
| OR | | |
| AZIMUTH CENTER OF SCAN (SCAN MODE ONLY) | 19 bit | |
| ELEVATION BIAS (COMPUTER MODE ONLY) | 19 bit AND SIGN | $\frac{360}{2^{19}}$ |
| OR | | |
| ELEVATION CENTER OF SCAN (SCAN MODE ONLY) | 19 bit | |
| LOCAL TIME (EST)* | 20 bit | 1 SECOND |

*Station time will be converted to G. M. T. only in the future.

TABLE 2

Display Translator Output Words

| WORD | LENGTH | LEAST SIGNIFICANT DECIMAL DIGIT |
|---|---|---|
| ANTENNA AZIMUTH | 6 DIGIT | 0.001 DEGREE |
| ANTENNA ELEVATION | 6 DIGIT | 0.001 DEGREE |
| COMMAND AZIMUTH | 6 DIGIT | 0.001 DEGREE |
| COMMAND ELEVATION | 6 DIGIT | 0.001 DEGREE |
| AZIMUTH BIAS (COMPUTER MODE ONLY) OR AZIMUTH CENTER OF SCAN (SCAN MODE ONLY) | 6 DIGIT AND SIGN 6 DIGIT | 0.001 DEGREE |
| LOCAL TIME (EST) | 6 DIGIT | 1 SECOND |
| GREENWICH TIME (GMT) | 6 DIGIT | 1 SECOND |

A block diagram of the Haystack Display Translator is shown in Fig. 1 and a signal flow chart is shown in Fig. 2. The input multiplex selects one of the six sets of 20 input lines and stores the 19-bit binary word on that set of lines in the flip-flop input storage. The 20th line is an inhibit signal which is used to indicate that the 19-bit word is correct. The 19-bit word corresponds to parts of one revolution. The word in input storage is then multiplied by a constant, $\frac{360,000}{2^{19}}$, to convert the word to thousandths of a degree. The binary output of the multiplier is passed through a binary to BCD converter to produce a 6 digit BCD number. The BCD number is then gated to the one set of six sets of six nixie drivers which corresponds to the set of input lines selected by the input multiplex. The Display Translator then repeats the entire conversion for the next set of input lines. The time for conversion of the number is 1.1 milliseconds and each set of nixie drivers receives a new set of numbers every 6.6 milliseconds. The plus and minus signs on azimuth and bias inputs go directly to a nixie driver for display. The input time is a 6 digit BCD number which corresponds to local station time. This number is sent to a set of six nixie drivers and at the same time goes to a conversion network which provides GMT hours output. The GMT hours output then goes to nixie drivers for display. The time nixie drivers

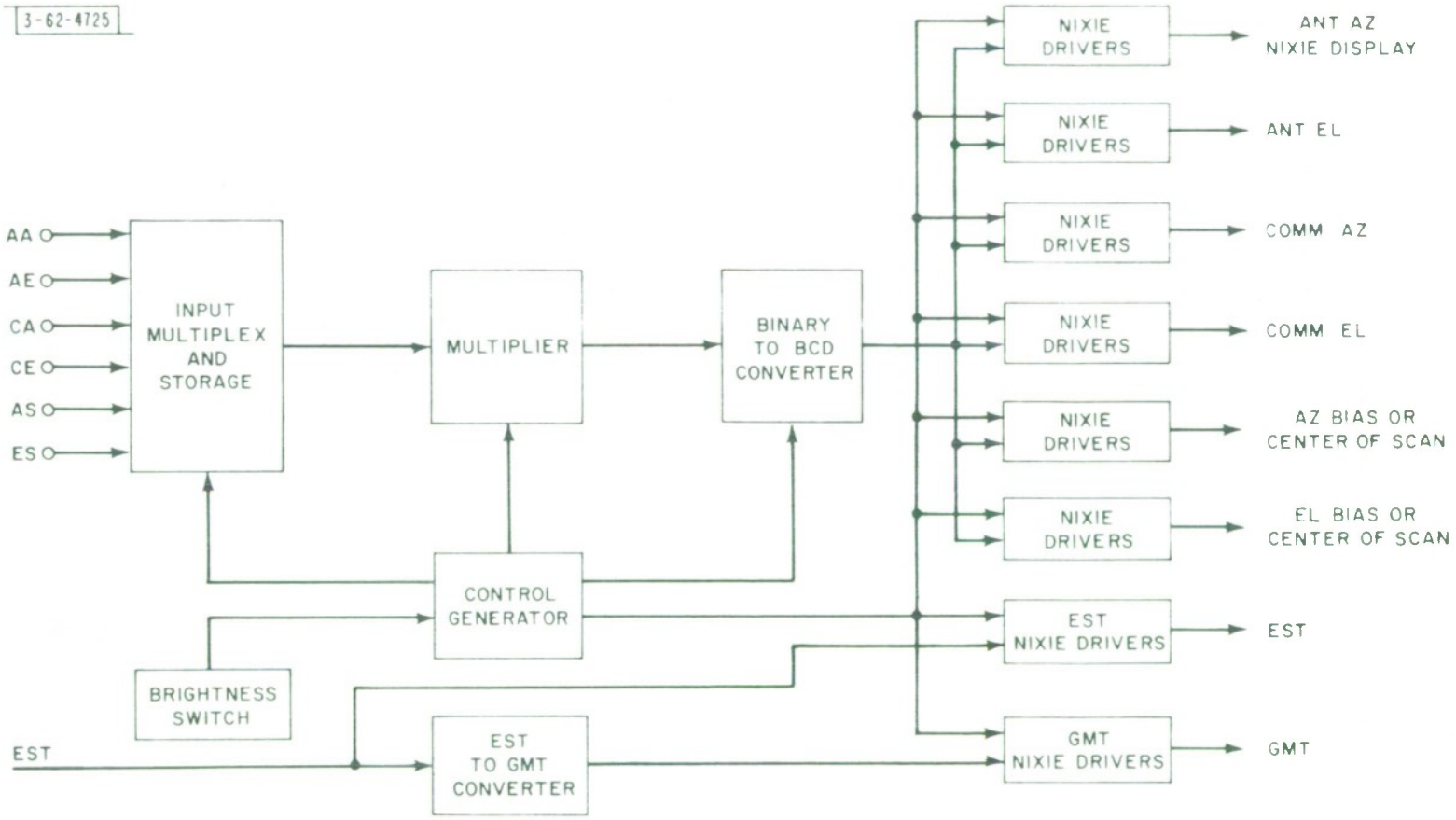



Fig. 1. Haystack display translator block diagram.

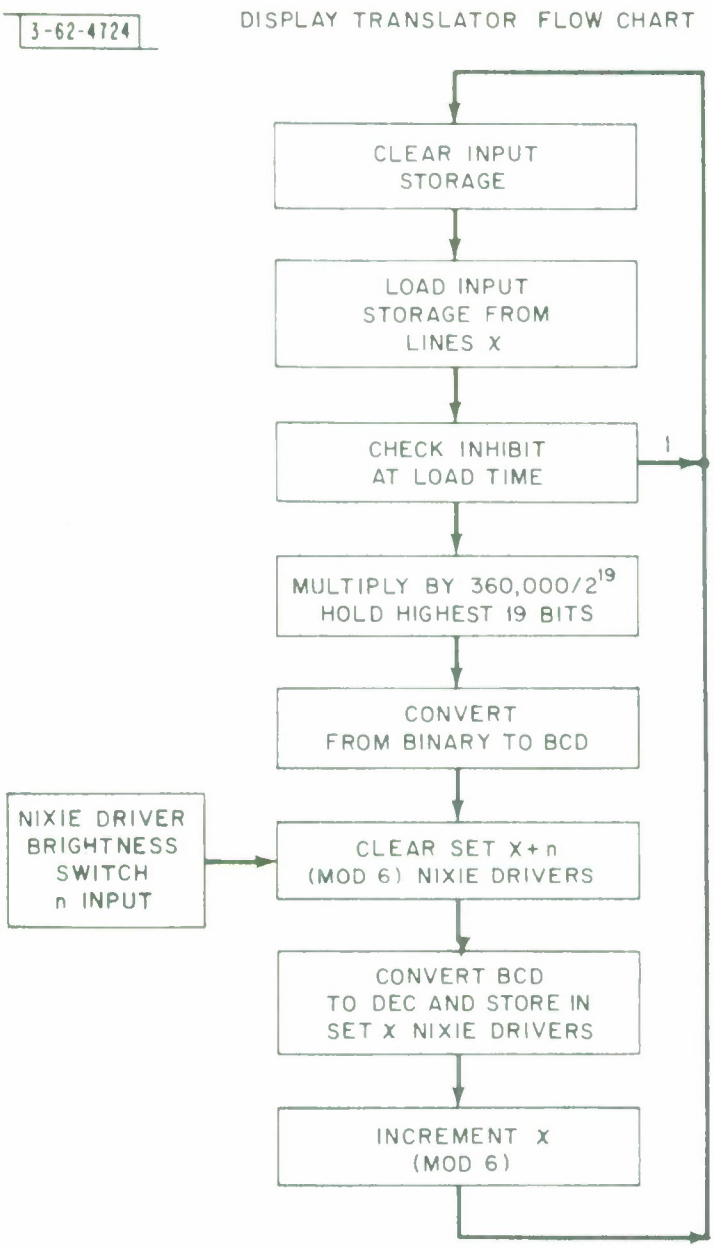



Fig. 2. Display translator flow chart.

are cleared and strobed every 6.6 milliseconds. The brightness of all the nixie indicators is varied by changing the length of time the nixies are turned on.

## PRINTED CIRCUIT CARDS

The Haystack Display Translator is constructed with cards made by Computer Control Company (3C). These cards are of the "nand" circuit type with the following logic levels:

"1" = –6 volts

"0" = 0 volts

More detailed information about all of the 3C cards can be found in their "Instruction Manual, Publications No. 71-113A".

## SYSTEM OPERATION

### A. Input Multiplex

The input multiplex consists of 20 six-input "exclusive OR" circuits, one for each of the nineteen data bits and one for the inhibit bit. A diagram of one stage of the input multiplex is shown in Fig. 3. The six sets of input lines are connected to the display translator through plugs $s_1$, $s_2$, and $s_3$ with position angles on $s_1$, command angles on $s_1$, command angles on $s_2$, and bias or center of scan angles on $s_3$. Whenever line $x_1$ is true, the 19 bits of word 1 are gated to the flip-flop storage register inputs and similarly for lines $x_2 \ldots x_6$. The 19 bits are loaded into the storage register when the "load input" line becomes true. The input storage flip-flops are cleared when the "clear input" line becomes true shortly before a new word is stored. The outputs of the 19 flip-flops (numbers and complements) are sent to the multiplier. The output of the inhibit gate is not stored but sent to the control generator.

### B. Multiplier

The multiplier consists of a 20-bit combined shift-register adder. A typical stage is shown in Fig. 4. A shift-left command shifts the contents of the 20-bit register one position to the left. The bit in the most significant flip-flop is shifted into the first stage of the binary to BCD converter and a zero is shifted into the least significant flip-flop from the right. A shift-right command shifts the contents of the

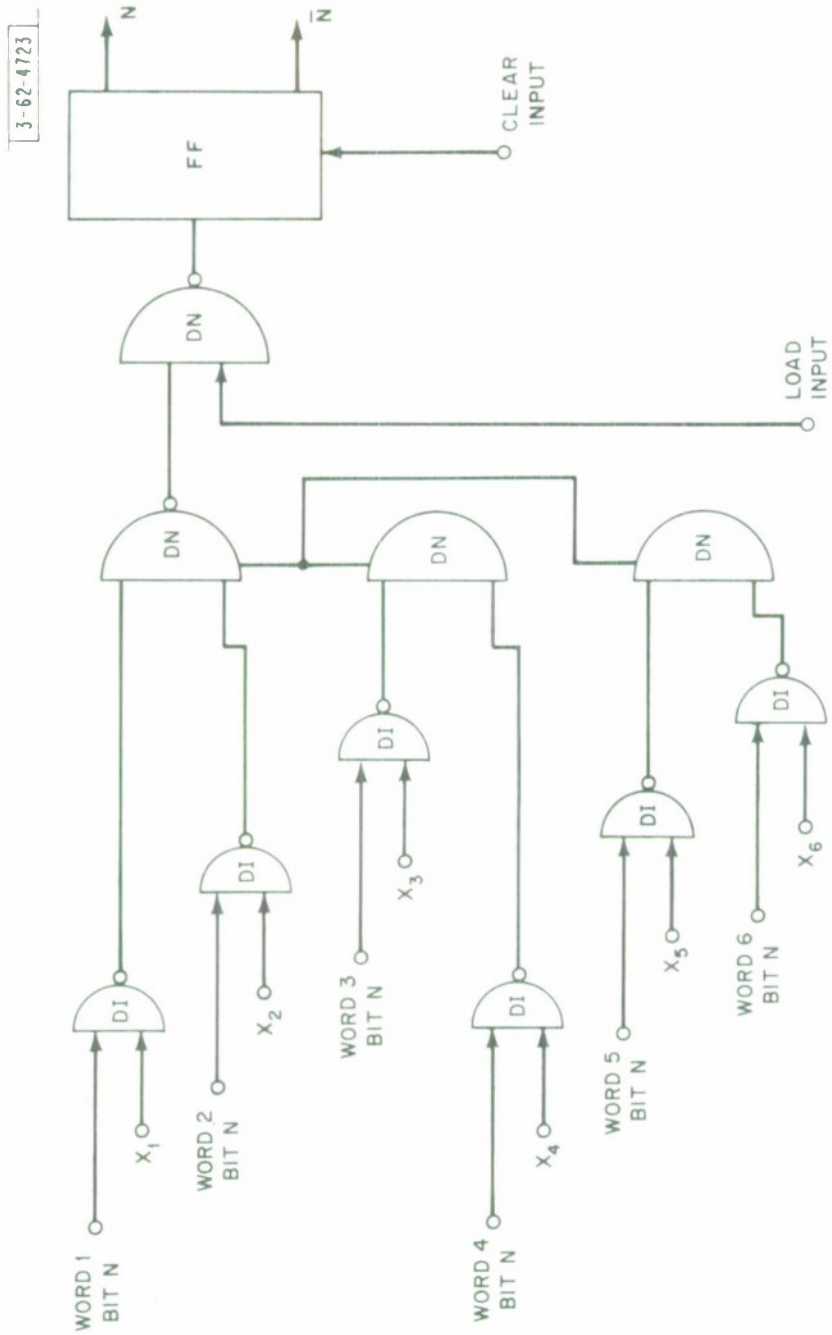



Fig. 3. One stage of input multiplex.

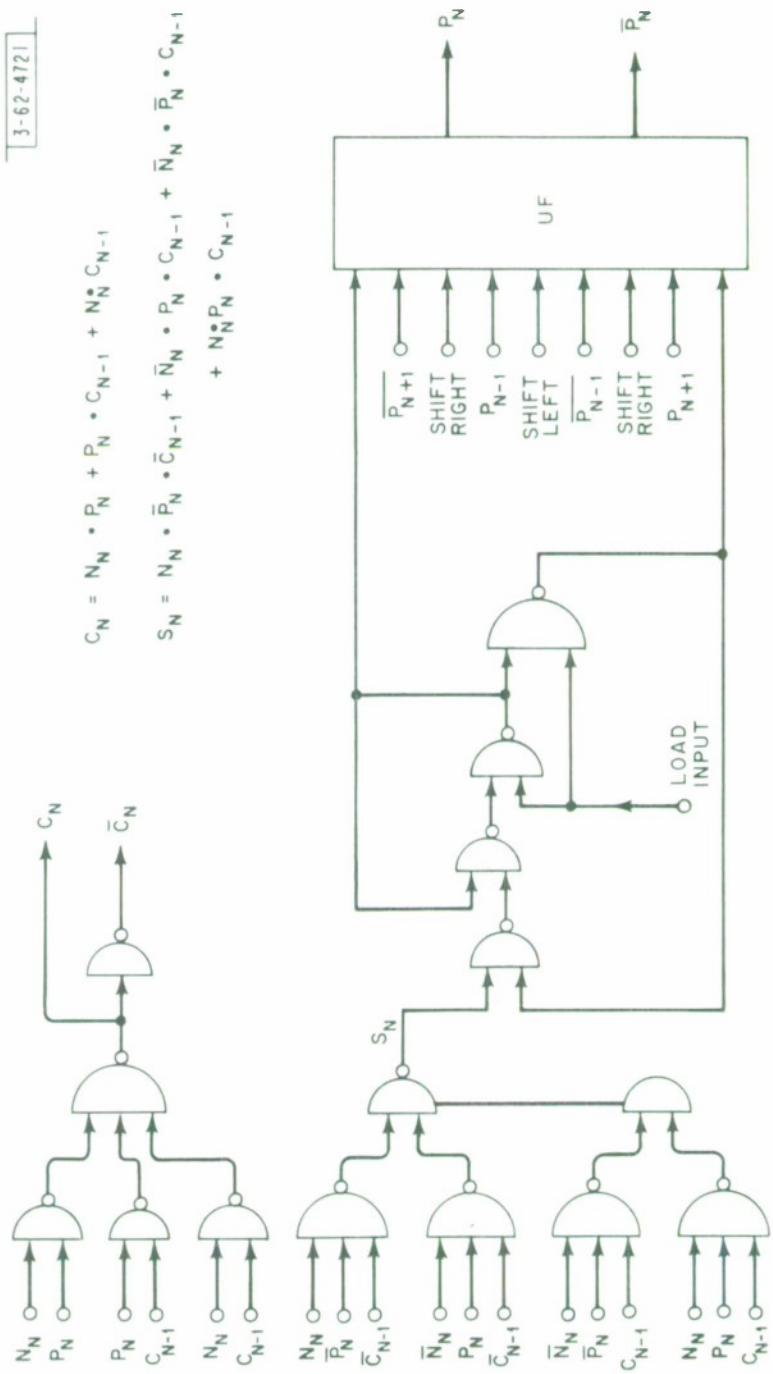



Fig. 4. Typical multiplier stage bit N.

20-bit register one position to the right. The least significant bit is lost and a zero is shifted into the most significant flip-flop from the left. A "load sum" command loads the 20-bit register with the outputs of the 20 sum and carry networks. Each sum and carry network adds the contents of an input storage flip-flop and the contents of the corresponding element of the 20-bit combined shift-add register to produce sum and carry bits for that element.

Consider multiplication of two binary numbers

| | | |
|---|---|---|
| MULTIPLICAND | 101101 | |
| MULTIPLIER | 1011 | |
| | 101101 | ADD-SHIFT (1) |
| | 101101 | ADD-SHIFT (1) |
| | 000000 | SHIFT (0) |
| | 101101 | ADD-SHIFT (1) |
| PRODUCT | 111101111 | |

For each "1" in the multiplier there is a corresponding add-then-shift operation, while for each "zero" in the multiplier there is only a shift operation.

The shift-add sequence in the multiplier was chosen by inverting the order of the desired constant multiplier (360,000 in binary) and replacing each "1" by an "add and shift-right" operation, and each zero with a "shift-right". The shift operation is performed on the partial sum.

The 19 "shift-left" pulses shift the binary word through the binary to BCD converter. Division by $2^{19}$ is accomplished by a shift of the binary point which is built into the shift register.

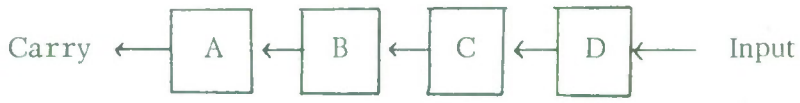
C. Binary to BCD Converter

The binary to BCD converter is a 24-bit shift register which converts the multiplied 19-bit binary word to a six digit BCD number. Each of six digit-sections of the converter function according to the rules of Table 3. A typical section is shown in Fig. 5. The outputs and complements of all the 24 flip-flops are sent to the nixie drivers. The Present states (P) of the registers A, B, C, and D are sensed and the Next states (N) are forced as a new bit is shifted in from the right.

TABLE 3

Showing the Allowable Present (P) States and the Desired Next (N) States of the Flip Flops in One Section of the BCD Register

One Section of BCD Register




| | Carry | A | B | C | D |
|---|---|---|---|---|---|
| P | 0 | 0 | 0 | 0 | 0 |
| N | 0 | 0 | 0 | 0 | x* |
| P | 0 | 0 | 0 | 0 | 1 |
| N | 0 | 0 | 0 | 1 | x |
| P | 0 | 0 | 0 | 1 | 0 |
| N | 0 | 0 | 1 | 0 | x |
| P | 0 | 0 | 0 | 1 | 1 |
| N | 0 | 0 | 1 | 1 | x |
| P | 0 | 0 | 1 | 0 | 0 |
| N | 0 | 1 | 0 | 0 | x |
| P | 0 | 0 | 1 | 0 | 1 |
| N | 1 | 0 | 0 | 0 | x |
| P | 0 | 0 | 1 | 1 | 0 |
| N | 1 | 0 | 0 | 1 | x |
| P | 0 | 0 | 1 | 1 | 1 |
| N | 1 | 0 | 1 | 0 | x |
| P | 0 | 1 | 0 | 0 | 0 |
| N | 1 | 0 | 1 | 1 | x |
| P | 0 | 1 | 0 | 0 | 1 |
| N | 1 | 1 | 0 | 0 | x |

*x means don't use.

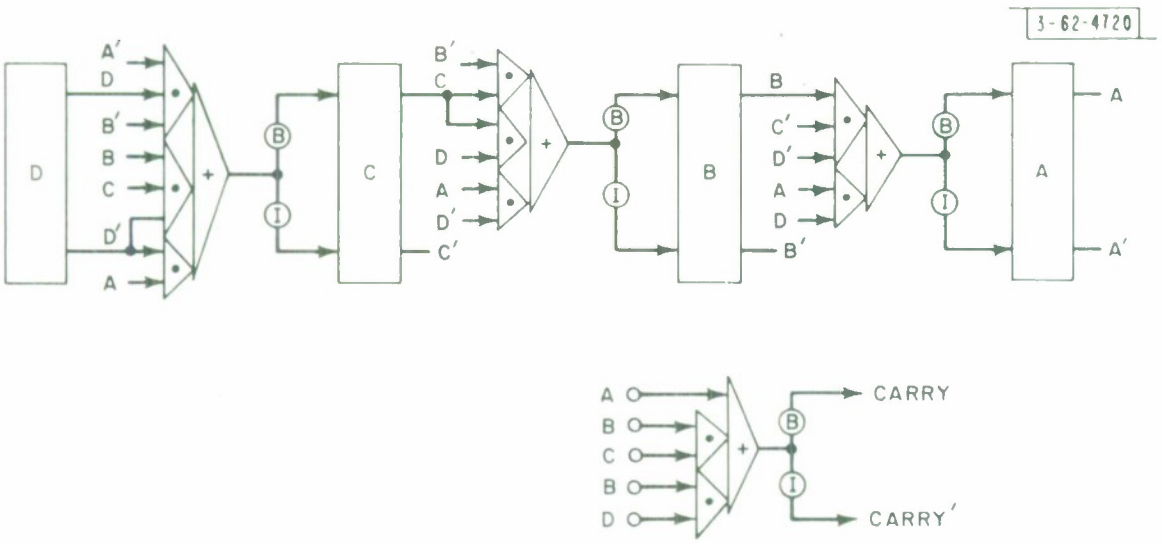



Fig. 5. Binary to BCD converter.

D. Nixie Drivers

Each decimal display (azimuth position, azimuth command, azimuth bias or center of scan, elevation position, elevation command, and elevation bias or center of scan) consists of six digits. The BCD inputs of corresponding digits are wired in parallel so that every translated word is presented to all six sets of nixie drivers. The selection of the set of six nixie drivers to be loaded is controlled by word counter No. 1 which also selects the set of input lines to be sampled. The loading is accomplished by a strobe or store pulse. Since each complete conversion takes 1100 $\mu$ seconds and there are 6 conversions for one whole cycle, each set of six nixie drivers receives a strobe pulse to load new data every 6.6 milliseconds. The brightness of the nixie indicators is controlled by the length of time between the strobe and the clear for each nixie driver.

The selection of the set of nixie drivers to be cleared during each conversion cycle is controlled by word counter No. 2. This counter can be preset by the brightness switch to any number between 0 and 5. Thus a set of nixie drivers may be cleared between 0 and 5 conversion cycles before new data is loaded into that set.

E. Control Generator

A block diagram of the control generator is shown in Fig. 6. A train of 5$\mu$ second wide pulses spaced 20 $\mu$ seconds apart is derived from a 100 kc crystal oscillator and gated to a 6-bit parallel counter. The gate is opened at the end of a conversion cycle to allow the counter to be cleared. Each of the pulse trains used in the display translator is produced either by gating the 5 $\mu$ second pulse train with selected states of the clock or using selected clock output states directly. The control generator timing diagram is shown in Fig. 7. The inhibit bit from the input multiplex is gated with the "load input" pulse to set a flip-flop if the two pulses occur simultaneously, in which case the counter is cleared. The brightness of the nixie displays is controlled by changing the length of time between strobing and clearing the drivers. Word counter No. 1 is a six state recycling counter which is advanced once each word conversion cycle. This counter selects the set of nixie drivers which are to be strobed at the same time it selects an input word. Word counter No. 2 is a similar counter which can be preset with a number from 0 to 5. Both counters are advanced

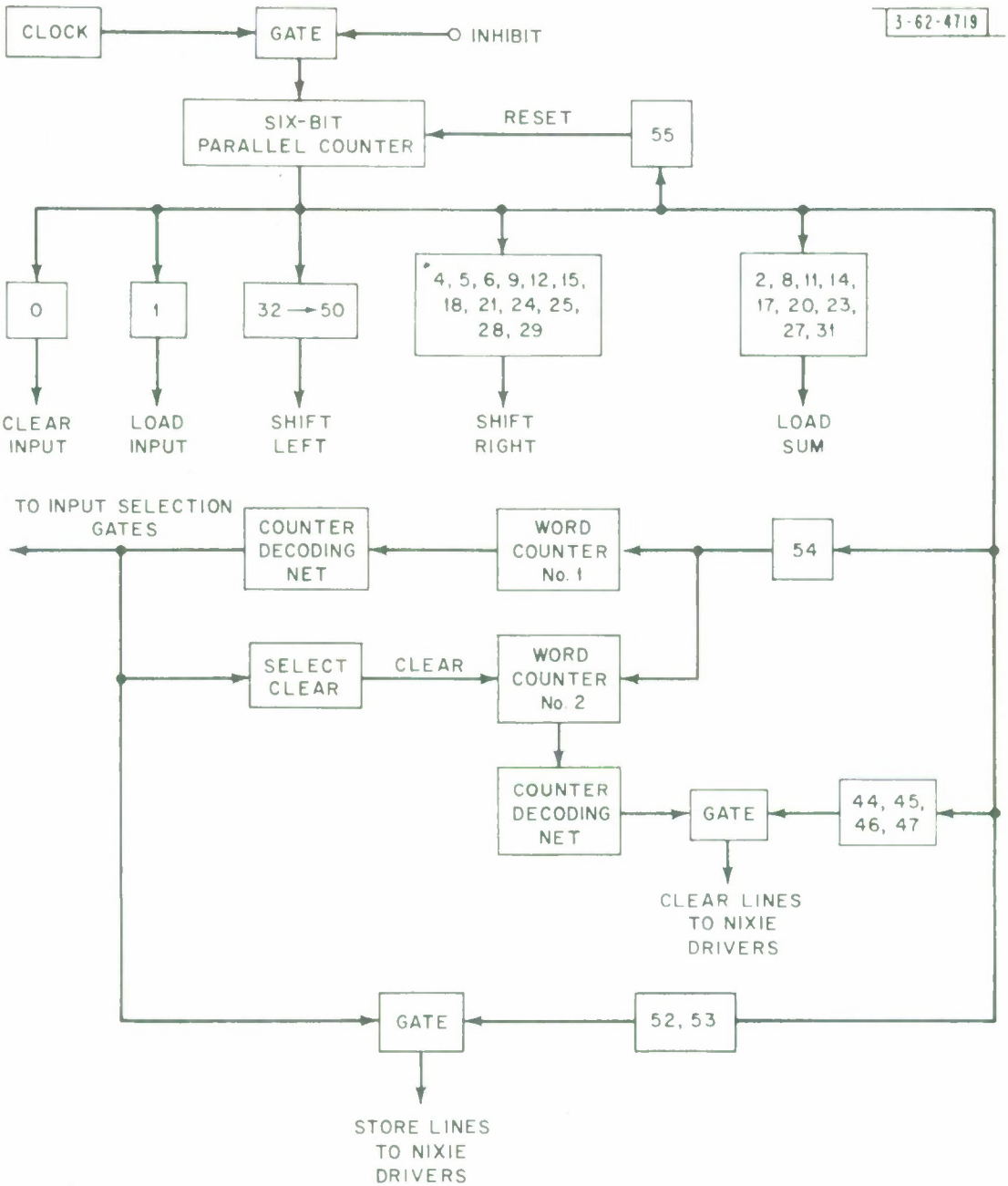



Fig. 6. Control generator block diagram.

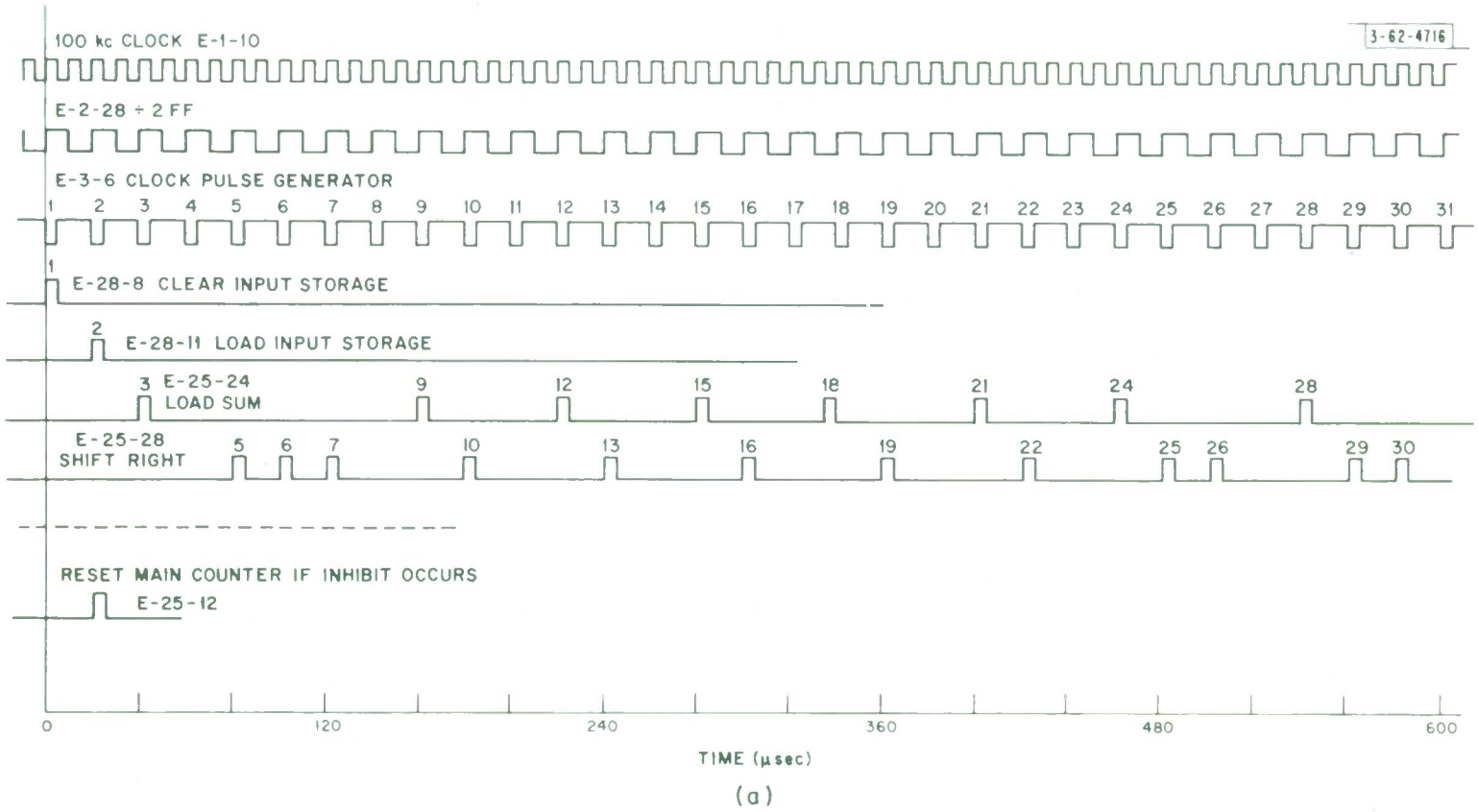



Fig. 7. Haystack display translator control generator timing.

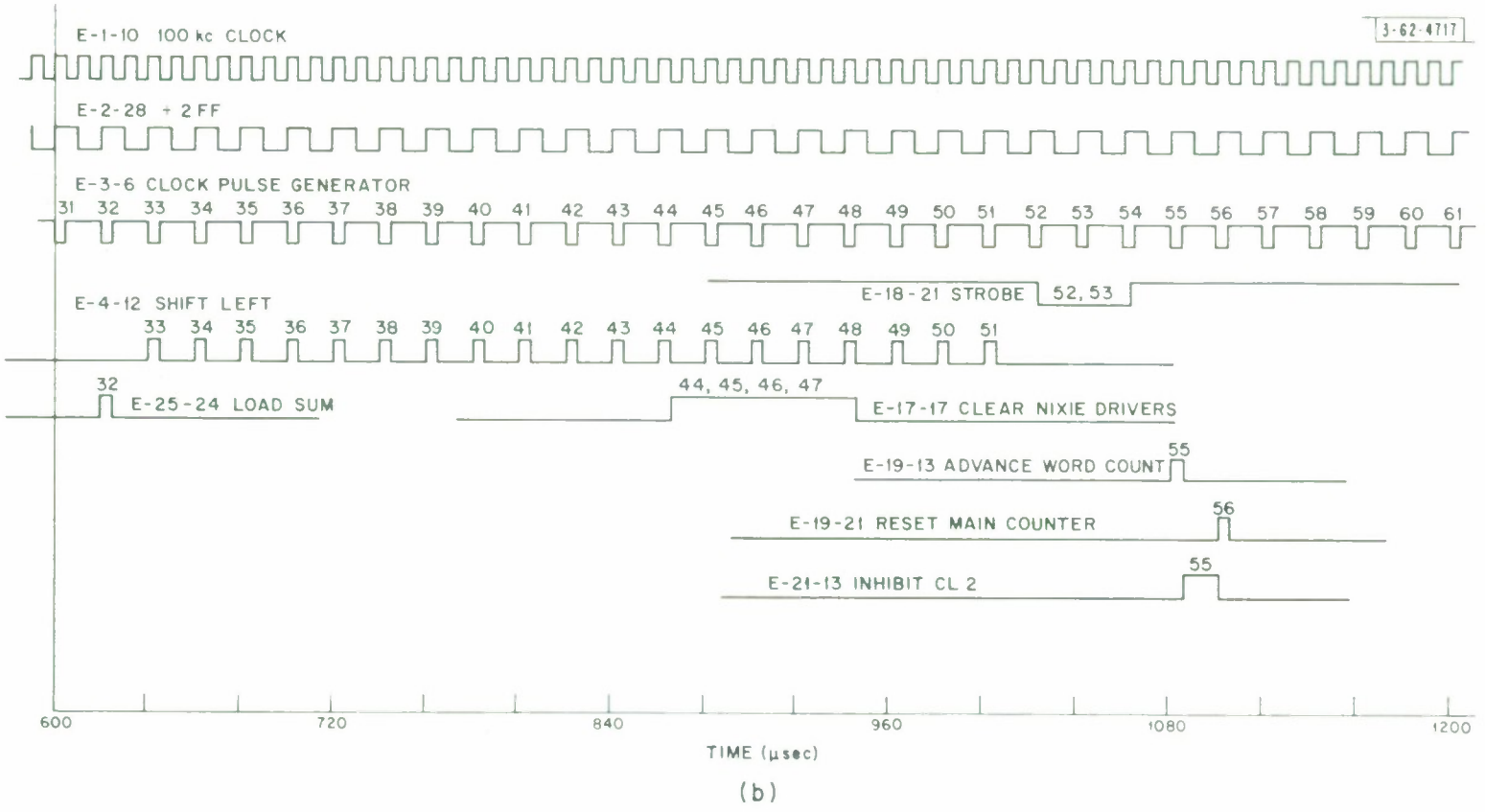



Fig. 7. Continued.

together but word count No. 2 determines which set of nixie drivers is to be cleared during the current word conversion cycle. The drivers are cleared in 1.1 msec steps from 1.1 ms to 6.6 msec after they are strobed. The set of strobe and clear pulses which drive the command azimuth nixie drivers are also sent to the General Purpose Input-Output[1] rack to control the brightness of three sets of nixie drivers located there (R.A., Dec., Hour Ang.).

F. Time

Time is brought in from the station clock as a six digit BCD word. Each of the lines goes to an inverter to produce the bit and its complement. The time word and its complement then go to the EST nixie drivers. The six BCD lines for EST hours also go to a conversion section (Fig. 8) which adds 5 hours (mod. 24) to the EST hours. The output of the conversion section drives two nixie drivers which provide GMT Hours output. All of the time nixie drivers are strobed and cleared at the same time as the azimuth center of scan or bias drivers.

G. Bias Signs

The azimuth and elevation bias sign inputs go to a nixie driver (Fig. 9) which drives a diode matrix to decode the high voltage nixie sign voltages produced.

H. Detailed Diagrams

Table 4 is a list of the detailed diagrams of the Haystack Display Translator.

1. A. F. Dockrey, J. E. Gillis, S. B. Russell, "General-Purpose I/O Channel and Interface for Haystack 490 Computer," Lincoln Laboratory Technical Note (in preparation).

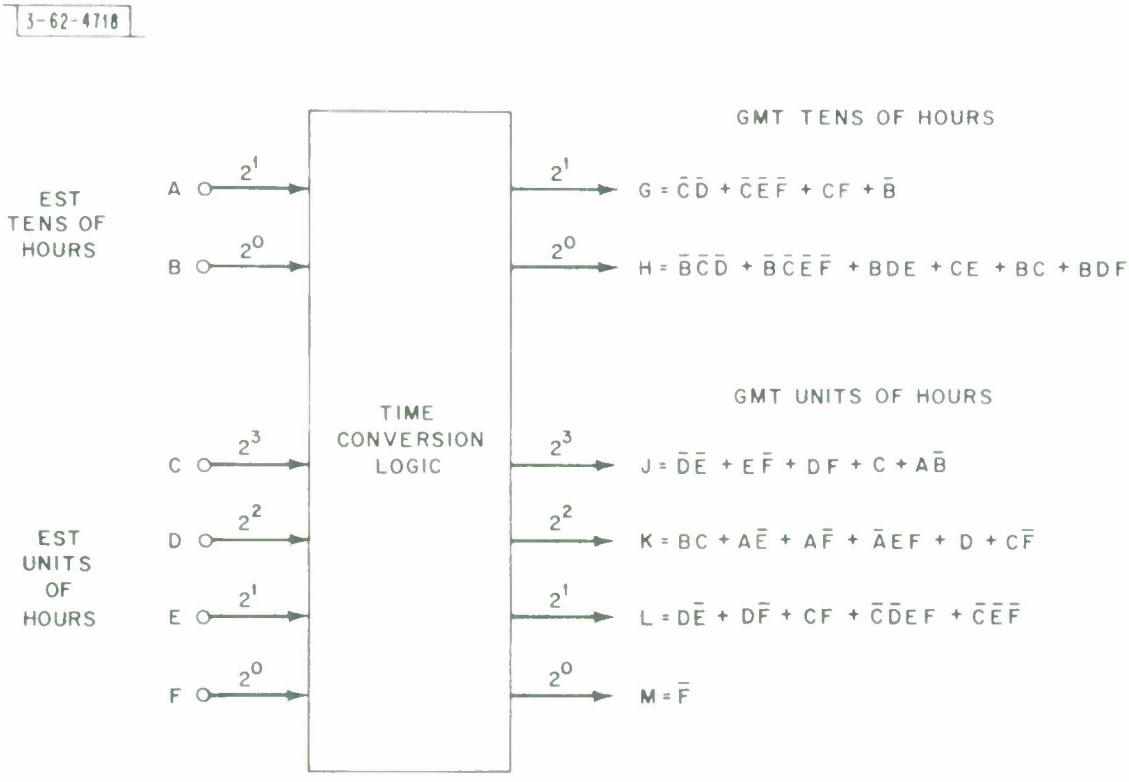



Fig. 8. Time conversion section.

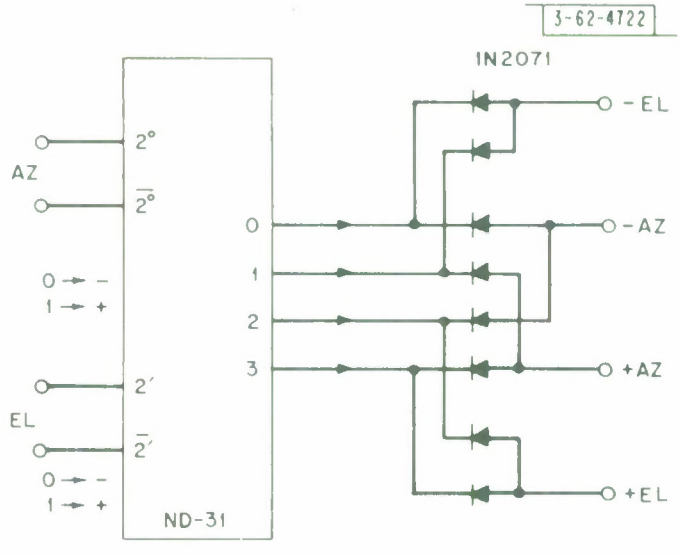



Fig. 9. Bias sign drivers.

TABLE 4

Haystack Display Translator
Detailed Logic Diagrams

| Lincoln Lab Drawing Number | |
|---|---|
| 23425 | Block Diagram |
| 23426 | Input Multiplex Bits 1-4 |
| 23427 | Input Multiplex Bits 5-8 |
| 23428 | Input Multiplex Bits 9-12 |
| 23429 | Input Multiplex Bits 13-16 |
| 23430 | Input Multiplex Bits 17-20 |
| 23431 | Shift and Add Stages 1-4 |
| 23432 | Shift and Add Stages 5-8 |
| 23433 | Shift and Add Stages 9-12 |
| 23434 | Shift and Add Stages 13-16 |
| 23435 | Shift and Add Stages 17-20 |
| 23436 | Binary to BCD Converter BCD Words 1 & 2 |
| 23437 | Binary to BCD Converter BCD Words 3 & 4 |
| 23438 | Binary to BCD Converter BCD Words 5 & 6 |
| 23439 | Control Generator Part 1 of 8 |
| 23440 | Control Generator Part 2 of 8 |
| 23441 | Control Generator Part 3 of 8 |
| 23442 | Control Generator Part 4 of 8 |
| 23443 | Control Generator Part 5 of 8 |
| 23444 | Control Generator Part 6 of 8 |
| 23445 | Control Generator Timing Diagram Part 1 of 2 |
| 23446 | Control Generator Timing Diagram Part 2 of 2 |
| 23447 | Nixie Drivers 5th Least Significant Digits all AZ-EL Displays |
| 23448 | Nixie Drivers 4th Least Significant Digits all AZ-EL Displays |
| 23449 | Nixie Drivers 3rd Least Significant Digits all AZ-EL Displays |
| 23450 | Nixie Drivers 2nd Least Significant Digits all AZ-EL Displays |
| 23451 | Nixie Drivers 1st Least Significant Digits all AZ-EL Displays |
| 23452 | Nixie Drivers Time and Bias Signs |
| 23453 | GMT Hours Conversion and Nixie Drivers |

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14. KEY WORDS

Haystack antenna  display systems  display translator